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Electro-Optics Lab Evaluation Deutsch Optical Waveguide Connectors

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Space Administration

John F. Kennedy Space Center



NASA Technical Memorandum 74108

Electro-Optics Lab Evaluation
Deutsch Optical Waveguide Connectors

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June 1980

N80-26572#

FOREWORD

Recent advances in technology have made the use of optical fiber communication more feasible. An important part of this growing technology is development of an effective method for connecting and disconnecting the optical fibers.

In an effort to determine the usefulness of current connector designs, NASA developed an optical fiber connector and splice evaluation test set. This report is the first in a series designed to present the results of NASA's studies.

This report documents the results of an evaluation of one vendor's connector, the Deutsch Optical Waveguide connector system. It is NASA's intent to locate at least one connector system which can be installed and used in a real-world field environment, while having minimum adverse effect on overall system performance.

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REFERENCE PUBLICATION

ELECTRO-OPTICS LAB EVALUATION

DEUTSCH OPTICAL WAVEGUIDE CONNECTORS

A REPORT BY

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SUMMARY

This evaluation has shown that the Deutsch connector system can conform to the manufacturer's specification of less than or equal to 1dB loss. The amount of loss in the connection seems to be very dependent upon the calibration of the connector installation tool. This problem could be solved with a redesigned tool and/or more frequent tool calibration. The connectors are reuseable and are easy to install.

The results of this work have been forwarded to Deutsch for their use in improving the connector system.

NASA will attempt to evaluate other connector systems as time and availability permit.

Introduction

This document reports an evaluation of the Deutsch Optical Waveguide connector system. The evaluation was conducted by NASA at Kennedy Space Center by the electro-optics lab of Design Engineering.

The connectors were evaluated in terms of both attenuation and bandwidth. Details of the attenuation evaluation are presented in this report and details of the bandwidth evaluation are presented in a report entitled "Optical Fiber Dispersion Characterization Study," Final Report Dec. 1979. Results of both evaluations are presented in this report.

EQUIPMENT AND PROCEDURES USED

Connector Description

The connector system evaluated is described in detail in Deutsch Optical Waveguide System bulletin 131. Briefly, the system consists of plugs, which are attached to the fiber; receptacles, which are used to connect two plugs to form a complete fiber, connection via a wet lens; and an installation tool for installing the plugs onto the fiber. Although Deutsch also makes a connector for use with single fiber cables, only the single fiber connector (no cable) was evaluated; however, the plug receptacle mating system is identical and similar results should be expected for the cable connector.

Attenuation Measurement Technique

The following discussions relate only to attenuation properties of the connectors. The measurements were structured to allow several attenuation properties to be determined simultaneously, allowing a better insight into:

1. Initial mate attenuation.
2. Repeatability.
3. Receptacle symmetry.
4. Loss Vs fiber flatness.

The measurement cycle was structured, as follows:

1. A group of 15 sets of two connectors and one receptacle each were selected randomly and each piece was numbered.
2. A plug was installed, using the Deutsch tool, following the manufacturer's instructions.

3. The fiber end in the plug was inspected with a microscope to determine fiber cleavage quality and surface flatness. Cleavages rated unacceptable were rejected for three reasons; excessive spur, lack of flatness, or lack of overall quality (see Appendix A, End Photos). Rejected ends were reterminated until an acceptable cleavage was obtained, and microphotographs were made of each cut. Ends rejected for spur showed a pointed flaw which extended from the tool contact point into the fiber core area. A rejection for "flatness" meant that there were excessive variations from the ideal of complete flatness across the face of the fiber end. "Overall quality" as a criterion for rejection referred to flaws, irregularities and other faults in the fiber end that did not fall into the other two criteria.
4. The second plug was installed and inspected in the same fashion.
5. The two plugs were mated in a receptacle following the vendor's instructions, and a measurement of connector insertion loss was recorded.
6. One plug then was demated completely and remated (cycled), and a second measurement was recorded.
7. The other plug was cycled in a similar manner, and a third measurement was recorded.
8. Both plugs then were removed and remated at the opposite ends of the same receptacle, and a fourth measurement was recorded.
9. Both plugs then were cycled in their new positions, making a total of six loss measurements.
10. Steps 2 through 9 were repeated for all connectors in the selected lot.

Measurement Test Set

The test set used to perform the attenuation measurements is shown in block diagram form in Fig. 1. The test set consists of a Light Emitting Diode (LED) source, an 800-meter fiber test loop, a silicon detector, and signal processing equipment.

The LED source operates at a wave length of approximately 820 nanometers and is modulated for synchronous detection at a rate of 488Hz.

The fiber loop is configured as two 400-meter lengths with the connector to be measured installed in the middle.

The detector is a large active area silicon photocell. The signal processing electronics consists of two lock-in amplifiers and a ratiometer connected to a precision digital volt meter and control computer.

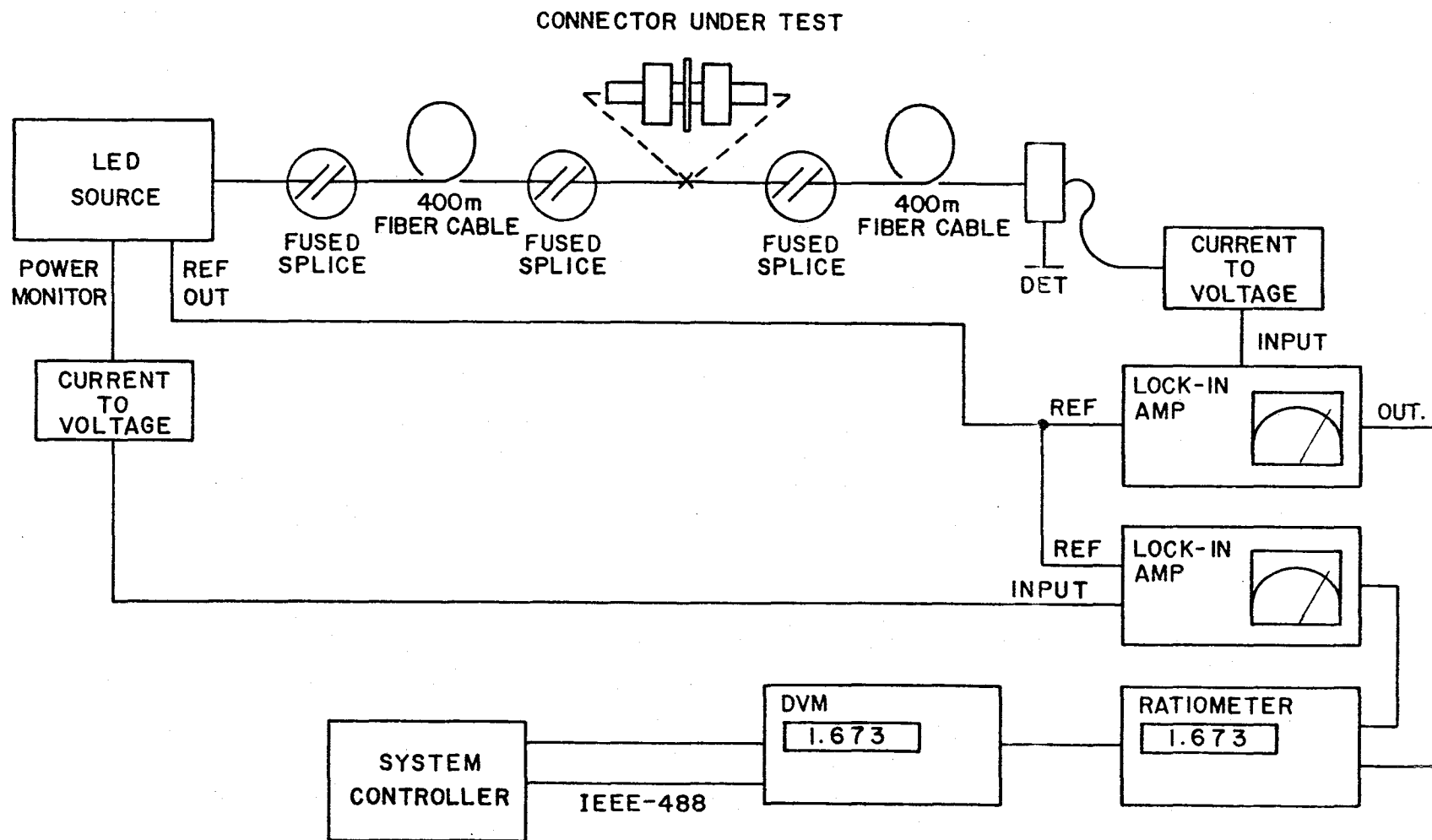


Figure 1. Test Set Used to Perform Attenuation Measurements.

All data were taken and reduced by computer. A program listing is included in Appendix B.

Details of the test set components are presented in Reference 1.

Measurement Procedure

The measurement procedure was followed for fifteen sets of connectors in the following manner:

Connectors parts used:

Connector plugs	Deutsch No. DW0001-08N	7827
Connector receptacles	Deutsch No. DW1000-08E	7909 Lot J-2
Termination tool	Deutsch No. DW9000	S/N 144

The termination tool was calibrated using the vendor's instructions, and a series of 10 connector sets, pairs 1 through 10, were measured. The results led to modification and recalibration of the termination tool. Five additional connector sets, adding pairs 11 through 15, then were measured after using the modified tool. The results for each series are presented as outlined below.

1. End photos of each connector set.
2. A data sheet of loss measurement for a particular connector set.
3. Three histograms, one for the first ten connectors, one for the remaining five connectors and one for all fifteen connectors.
4. A data table summarizing the measurements.

The end photos were taken with a reflection-type microscope set at 435 power. End flatness was measured by using the focusing mechanism of the microscope while observing the fiber end with a shallow depth of field.

The data sheets present all six absolute loss measurements and the five relative changes experienced. All measured values are expressed in decibels (dB).

The three histograms group the connector sets to the closest 0.1 dB and count each of the six measurements of a connector set as an independent measurement. The reader can make other correlations between various test conditions and connector measurements.

Bandwidth Measurements and Results

The bandwidth of these connectors was measured by using a time domain pulse dispersion test set developed by NASA with the aid of the University of Central Florida, Orlando, Florida. Details of the test set and measurement results are presented in a work entitled "Optical Fiber Dispersion

Characterization Study," NAS10-9455, Final Report Dec. 1979. As described in the report, a total of nine Deutsch connectors were installed in the middle of a 1.2 Km fiber loop.

The fiber bandwidth was determined with and without the connectors, and deconvolution was used to determine the effects of the connectors alone. The connectors demonstrated a bandwidth greater than the upper range of the test set, 2GHz, and in fact, all nine connectors combined had a 3 db bandwidth of greater than 2GHz.

DISCUSSION

Before any conclusion is drawn, it should be noted that it is not the intent of this report to imply Government recommendation or rejection of this connector system. It merely reports a result of NASA's search for a single fiber connector.

The Deutsch connector system was selected for evaluation for several reasons. First, the connector can be terminated under rough field conditions, without the use of polishing equipment or epoxies. Second, the total connection is reusable; if a poor connection is made, all the connector parts can be used again. Third, the connector is large enough to allow "untrained" individuals to use it with minimal risk of fiber or connector damage. Fourth, the same receptacle can be used with either single fiber or single fiber cable, allowing a convenient transition where necessary. Finally, the manufacturer claims a maximum loss of 1 dB. It is NASA's intention to evaluate other connector systems as availability and time permit.

CONCLUSION

Advantages

The Deutsch connector system was easy to install and proved to be reusable, as claimed. The quality of the fiber end seems to have little effect on the connector's performance, due to the wet lens design of the receptacle.

Total installation time for a connector and two plugs was approximately five minutes. Use of the connector system requires minimal training, and can be performed in most environments.

The connectors can be used in both inline and bulkhead applications. The common plug design, identical for both single fiber and fiber cable, provides a possible transition between single fiber, i.e., laser or APD pigtail, and a fiber cable.

The connector bandwidth was measured and reported as noted before in "Optical Fiber Dispersion Characterization Study," Final Report - December 1979. The connector bandwidth was greater than the upper limit of the measurement test set, 2GHz, and even when nine connectors were placed in series, the combined bandwidth still was greater than 2GHz. This indicates that the connectors would have little or no effect on the overall system bandwidth of most practical systems.

Disadvantages

The connectors did not meet the vendor's spec of loss, less than or equal to 1 dB, in all cases and showed a large variation between repeated matings. These problems seem to be largely related to the condition and calibration of the termination tool, as the last five connector pairs showed much better initial loss and repeatability.

The tool modification performed during this evaluation consisted of adding brass shim material to improve the tolerance of the fiber cutting mechanism and epoxying the fiber length adjustment to prevent accidental movement. Deutsch is designing a new tool.

The connector contains a fluid which can become contaminated with repeated matings and dematings.

RECOMMENDATIONS

In the current stage of development of fiber connector systems, the Deutsch system appears to enjoy several advantages in terms of expertise required, equipment needed and time spent in making connections. A series of long-term measurements are planned to determine the effects of time on this and other connector systems. It is NASA's intention to evaluate other connector systems as availability and time permit.

DATA TABLE 1: Measurements in dB for end pairs 1-15

<u>Pair</u>	<u>Initial</u>	<u>Cycles</u>	<u>Cycles</u>	<u>SWAP</u>	<u>Cycles</u>	<u>Cycles</u>	<u>Average</u>
1	-1.39	-1.33	-1.120	-1.71	-1.61	-1.6	-1.46
2	-1.38	-1.37	-2.25	-2.26	-2.32	-1.77	-1.89
3	-1.66	-1.78	-2.07	-2.48	-2.40	-2.32	-2.12
4	-0.99	-1.07	-1.29	-0.85	-0.67	-0.70	-0.93
5	-0.77	-0.68	-0.81	-0.68	-0.68	-0.77	-0.73
6	-0.88	-0.96	-0.93	-0.95	-0.95	-0.95	-0.94
7	-1.01	-1.10	-0.91	-0.71	-0.91	-0.93	-0.93
8	-0.58	-0.61	-0.63	-0.74	-0.76	-0.74	-0.68
9	-0.86	-0.90	-0.87	-1.26	-1.47	-1.45	-1.14
10	-0.94	-1.08	-1.23	-0.95	-0.92	-0.92	-1.01
11	-0.89	-0.96	-0.98	-0.85	-0.86	-0.83	-0.90
12	-1.22	-1.24	-1.28	-0.69	-0.67	-0.57	-0.95
13	-0.63	-0.70	-0.73	-0.57	-0.58	-0.59	-0.63
14	-0.46	-0.45	-0.46	-0.63	-0.57	-0.61	-0.53
15	-0.84	-0.77	-0.84	-0.93	-1.00	-0.94	-0.89

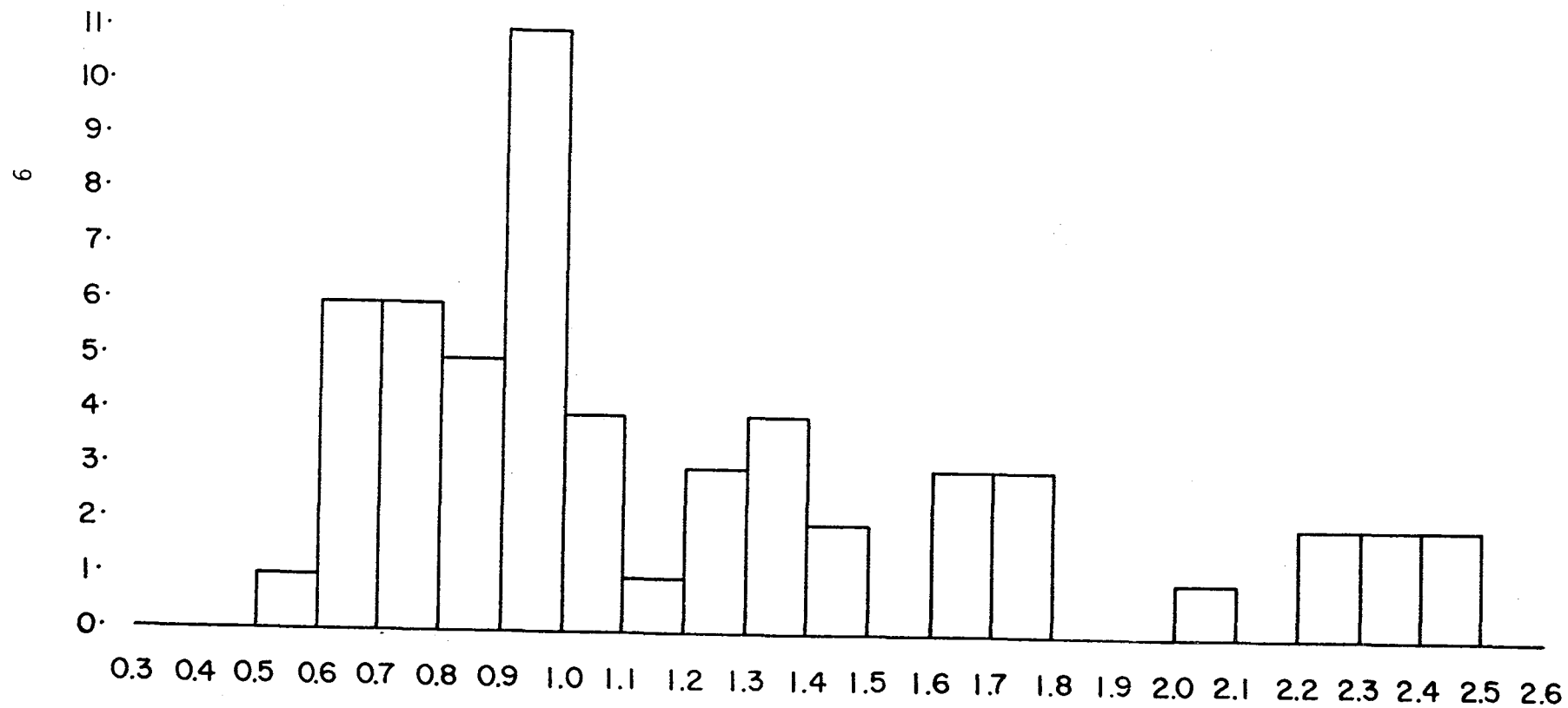


Figure 2. Histogram: Pairs 1-10

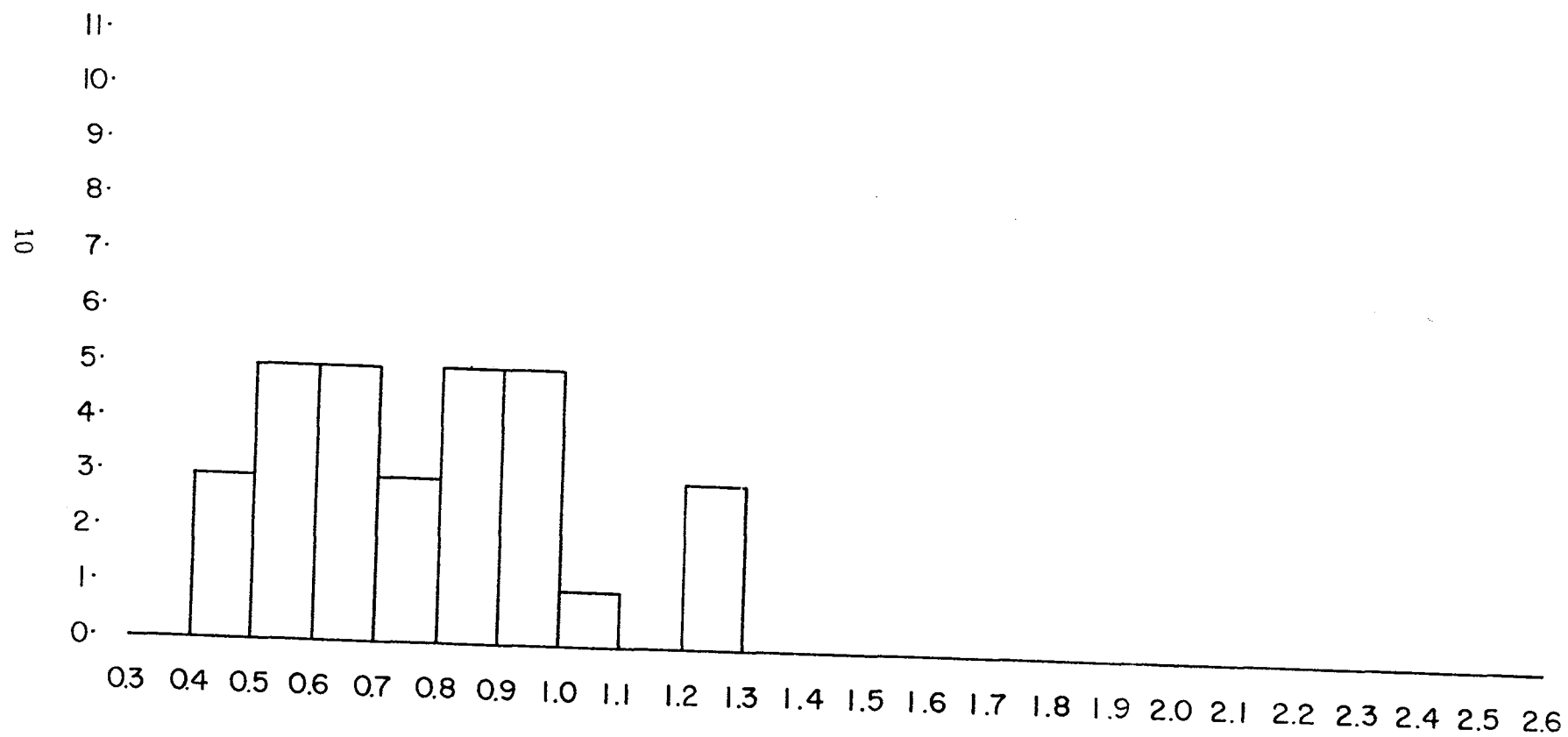


Figure 3. Histogram: Pairs 11-15

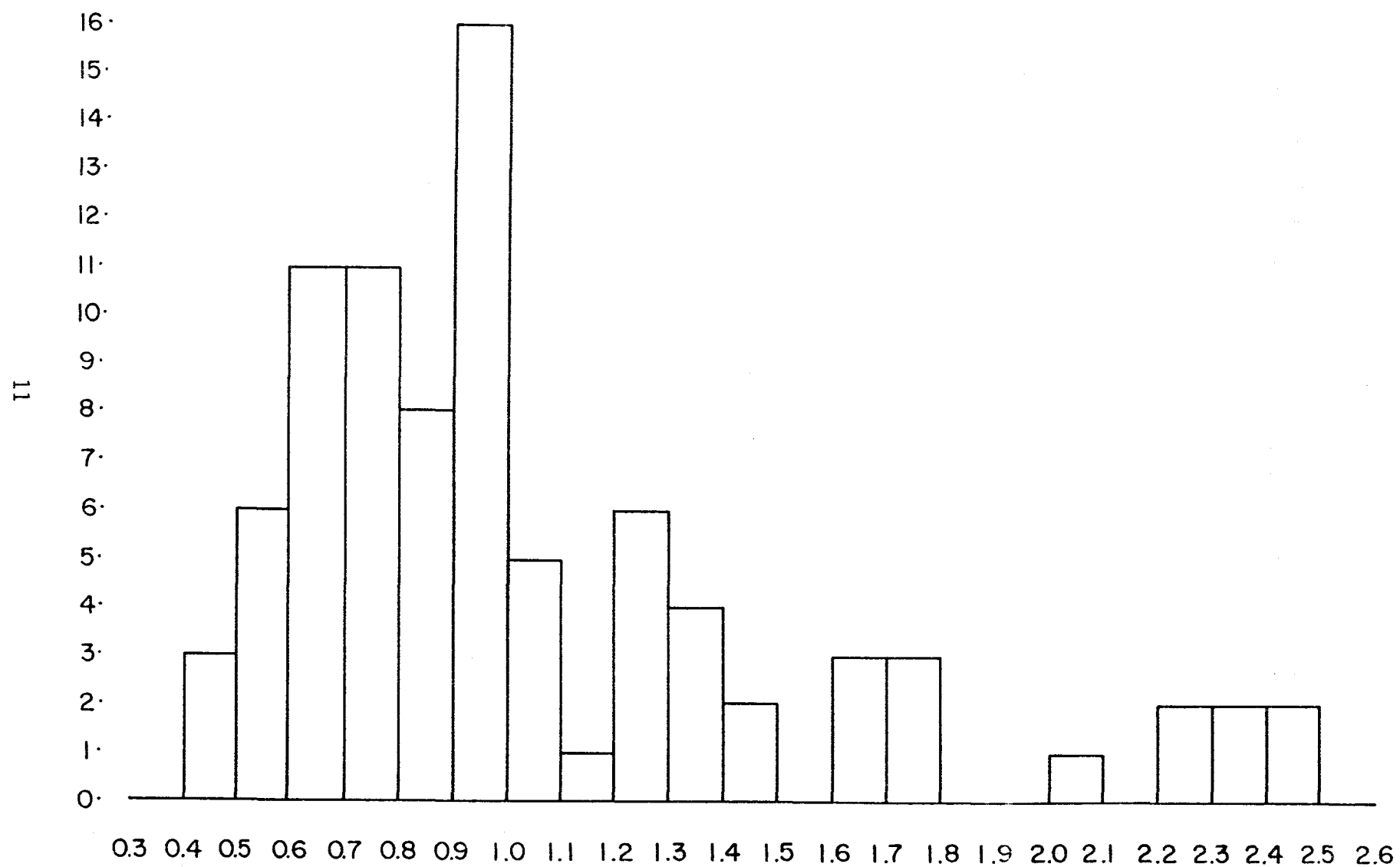


Figure 4. Histogram: Pairs 1-15

REFERENCES

1. M. E. Padgett, "The Measurement of Long Term Variations in Optical Fiber Attenuation and Numerical Aperture." Thesis University of Central Florida, Orlando, Florida, September 1979, to be published.

Appendix A

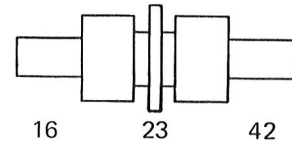
Connector Pairs End Photos

and

Loss Measurements

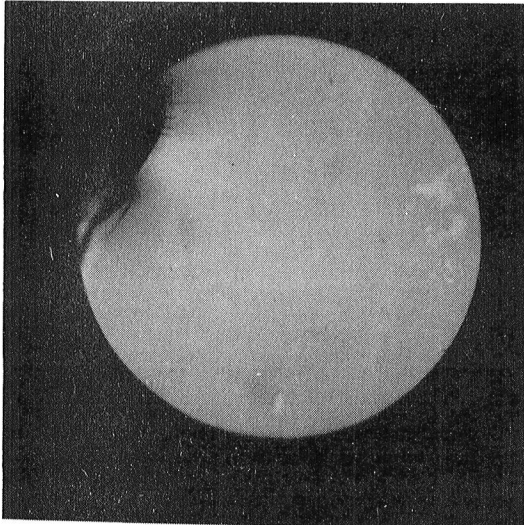
CONNECTOR PAIR #1

PLUG #16
PLUG #42
PLUG #23

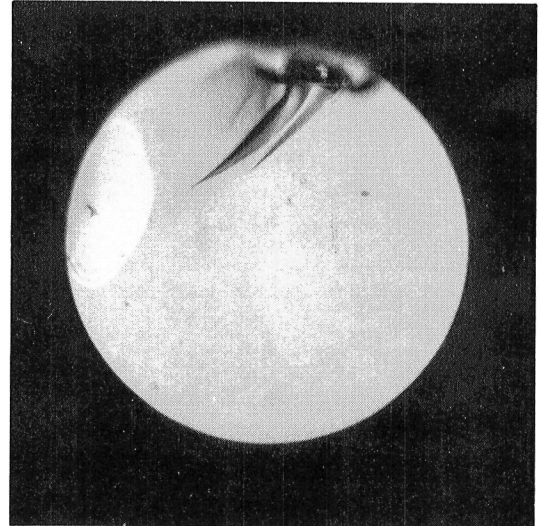


DATA COLLECTED ON 9-19-79

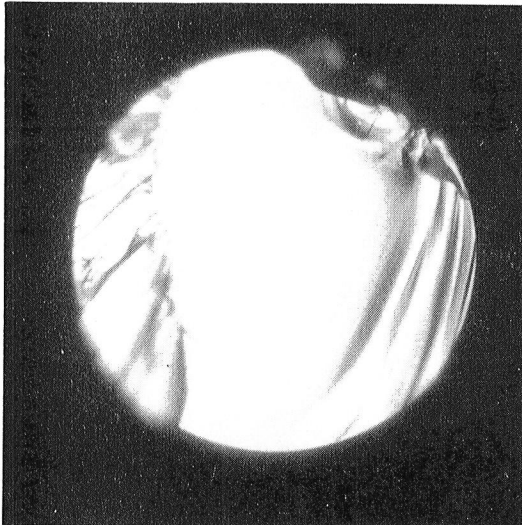
END PHOTOS



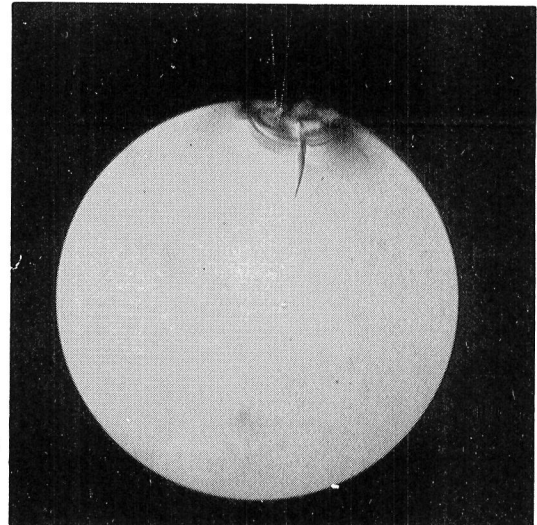
PLUG #16
FLATNESS= 4 μ m
ACCEPTED



PLUG #42 END
FLATNESS= 2 μ m
REJECTED FOR
SPUR



PLUG #42 END
FLATNESS=\$\$ μ m
REJECTED FOR
OVERALL QUALITY



PLUG #42 END
FLATNESS= 2 μ m
ACCEPTED

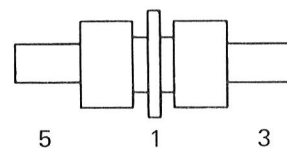
LOSS MEASUREMENTS

	CHANGE	ABSOLUTE LOSS THIS MATING
INITIAL LOSS		-1.390
CYCLE END #16	0.060	-1.330
CYCLE END #42	0.270	-1.120
TURN RECP AROUND	-0.320	-1.710
CYCLE END #16	-0.220	-1.610
CYCLE END #42	-0.210	-1.600

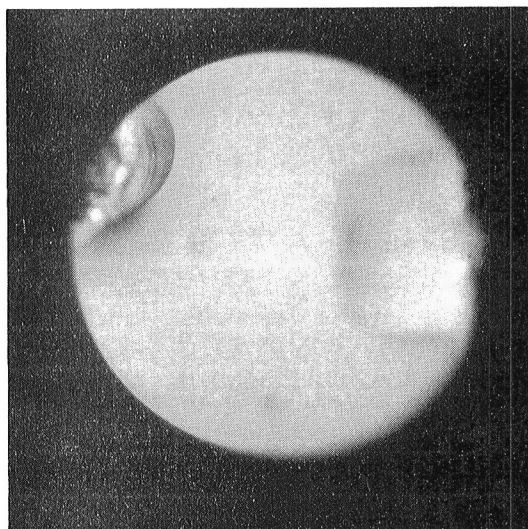
CONNECTOR PAIR #2

PLUG #5
PLUG #3
RECP #1

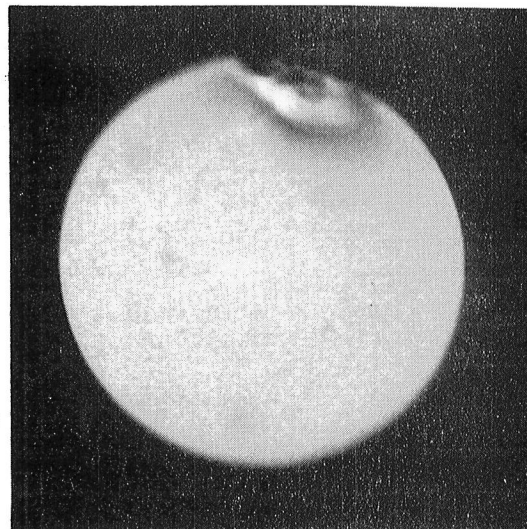
DATA COLLECTED ON 9-19-79



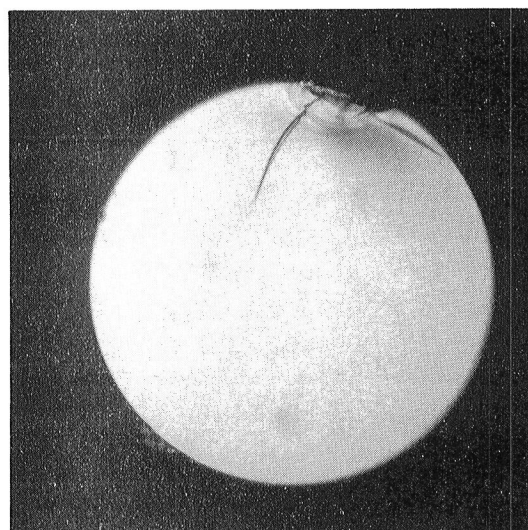
END PHOTOS



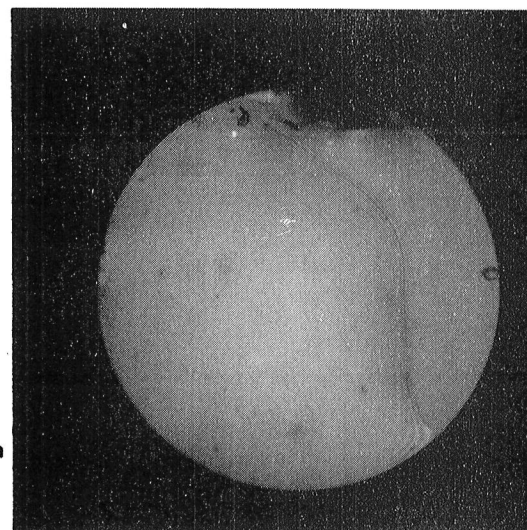
PLUG #5 END
FLATNESS= 8 μ m
REJECTED FOR
OVERALL QUALITY



PLUG #5 END
FLATNESS= 14 μ m
REJECTED FOR
FLATNESS



PLUG #5 END
FLATNESS= 4 μ m
ACCEPTED



PLUG #3 END
FLATNESS= 4 μ m
ACCEPTED

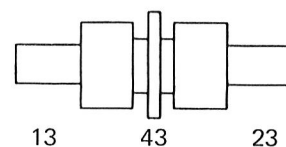
LOSS MEASUREMENTS

	CHANGE	ABSOLUTE LOSS THIS MATING
INITIAL LOSS		-1.380
CYCLE END #5	0.010	-1.370
CYCLE END #3	-0.870	-2.250
TURN RECP AROUND	-0.880	-2.260
CYCLE END #5	-0.940	-2.320
CYCLE END #3	-0.390	-1.770

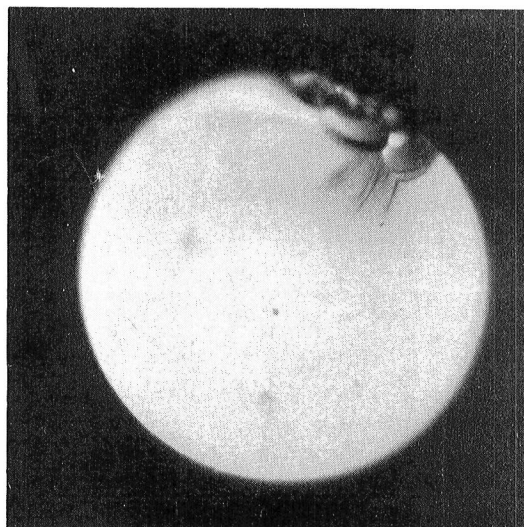
CONNECTOR PAIR #3

PLUG #13
PLUG #23
RECP #43

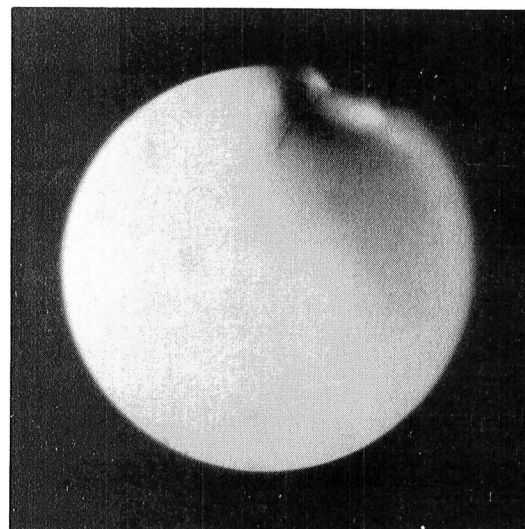
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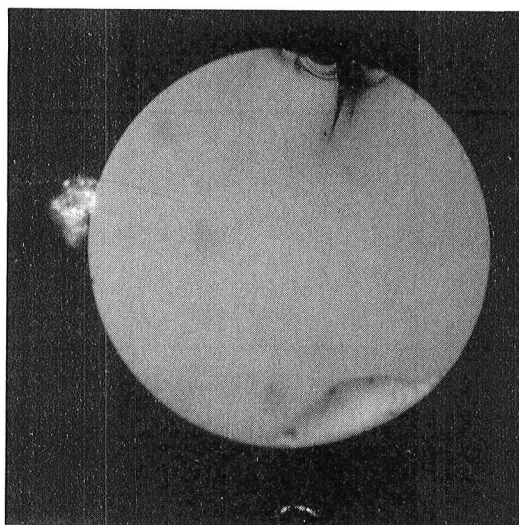
END PHOTOS



PLUG #13 END
FLATNESS= 14 μ m
REJECTED FOR
SPUR



PLUG #13 END
FLATNESS= 12 μ m
ACCEPTED



PLUG #23 END
FLATNESS= 3 μ m
ACCEPTED

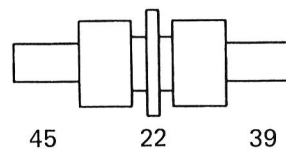
LOSS MEASUREMENTS

	CHANGE	ABSOLUTE LOSS THIS MATING
INITIAL LOSS		-1.660
CYCLE END #13	-0.120	-1.780
CYCLE END #23	-0.410	-2.070
TURN RECP AROUND	-0.820	-2.480
CYCLE END #13	-0.740	-2.400
CYCLE END #23	-0.660	-2.320

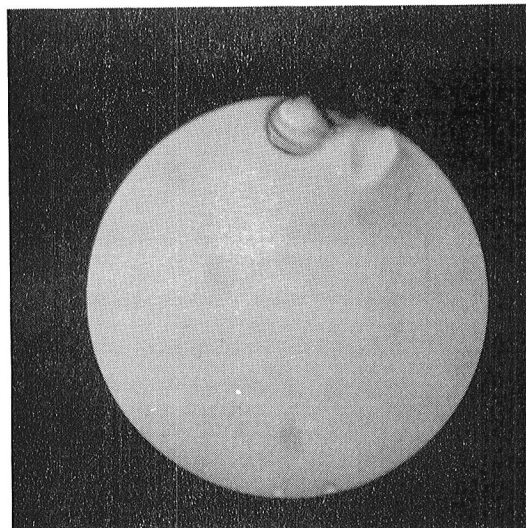
CONNECTOR PAIR #4

PLUG #45
PLUG #39
RECP #22

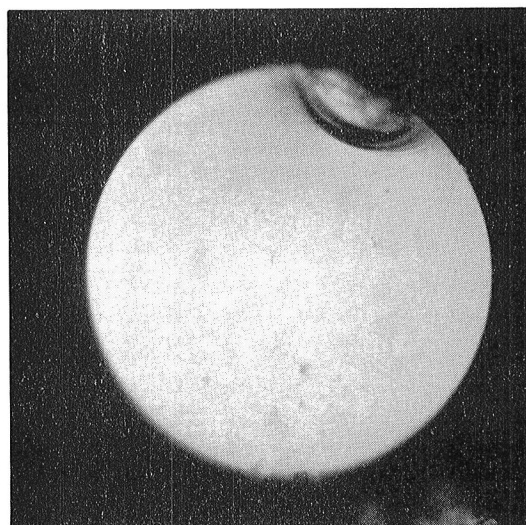
DATA COLLECTED ON 9-19-79



END PHOTOS



PLUG #45
FLATNESS= 4 um
ACCEPTED



PLUG #39 END
FLATNESS= 7 um
ACCEPTED

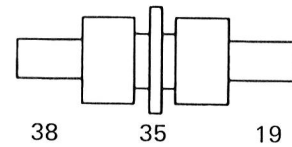
LOSS MEASUREMENTS

	CHANGE	ABSOLUTE LOSS THIS MATING
INITIAL LOSS		-0.990
CYCLE END #45	-0.080	-1.070
CYCLE END #39	-0.300	-1.290
TURN RECP AROUND	0.140	-0.850
CYCLE END #45	0.320	-0.670
CYCLE END #39	0.290	-0.700

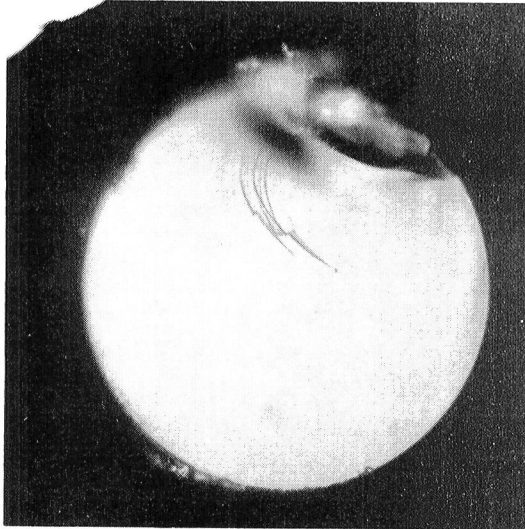
CONNECTOR PAIR #5

PLUG #38
PLUG #19
RECP #35

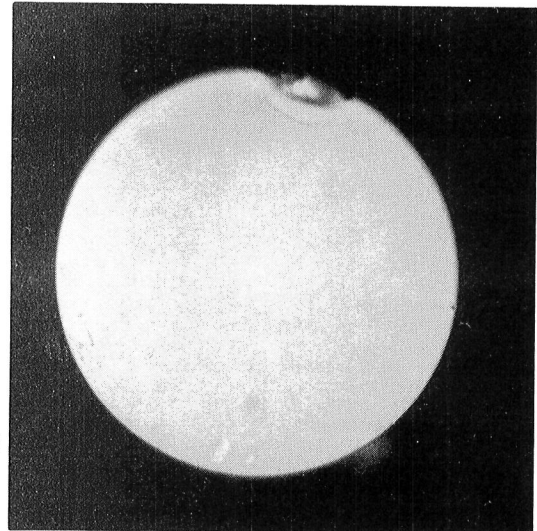
DATA COLLECTED ON 9-19-79



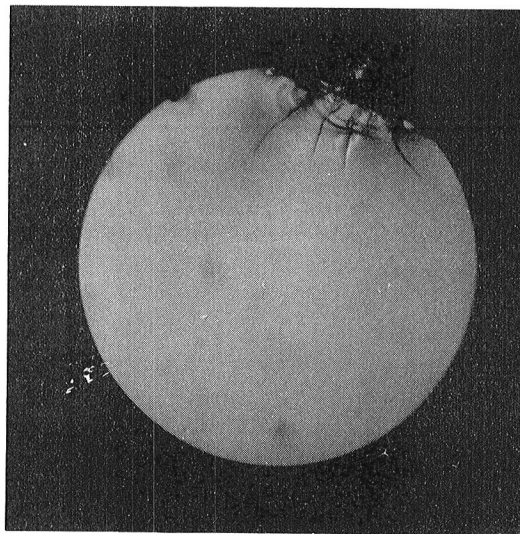
END PHOTOS



PLUG #38 END
FLATNESS= 7 μ m
REJECTED FOR
SPUR



PLUG #38 END
FLATNESS= 7 μ m
ACCEPTED



PLUG #19 END
FLATNESS= 2 μ m
ACCEPTED

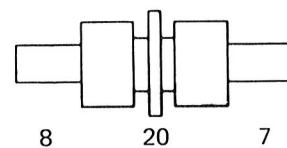
LOSS MEASUREMENTS

	CHANGE	ABSOLUTE LOSS THIS MATING
INITIAL LOSS		-0.700
CYCLE END #38	0.020	-0.680
CYCLE END #19	-0.110	-0.810
TURN RECP AROUND	0.020	-0.680
CYCLE END #38	0.020	-0.680
CYCLE END #19	-0.070	-0.770

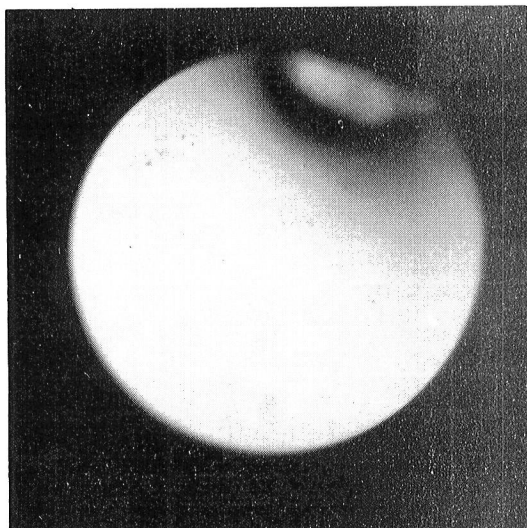
CONNECTOR PAIR #6

PLUG #8
PLUG #7
RECP #20

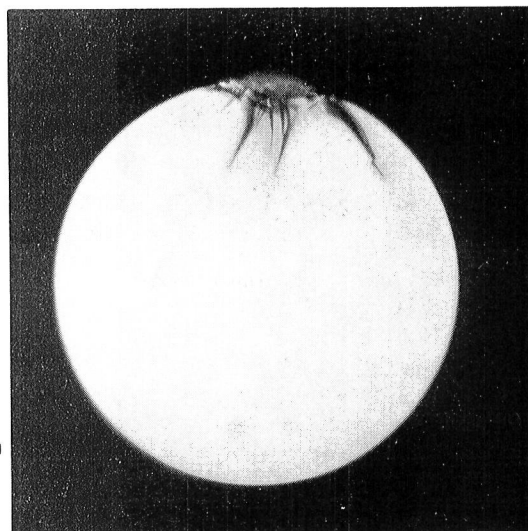
DATA COLLECTED ON 9-19-79



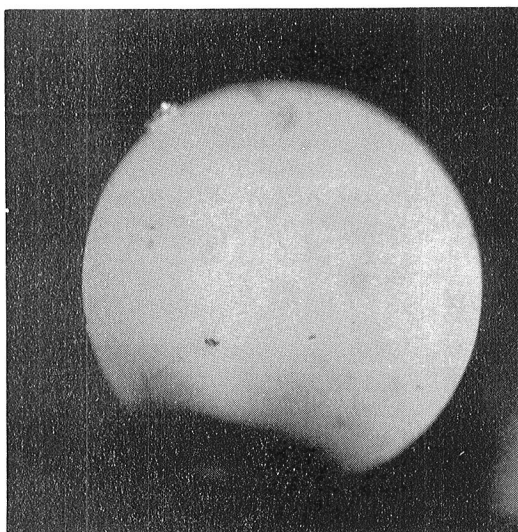
END PHOTOS



PLUG #8 END
FLATNESS= 17 μ m
REJECTED FOR
FLATNESS



PLUG #8 END
FLATNESS= 3 μ m
ACCEPTED



PLUG #7 END
FLATNESS= 13 μ m
ACCEPTED

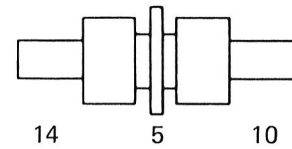
LOSS MEASUREMENTS

	CHANGE	ABSOLUTE LOSS THIS MATING
INITIAL LOSS		-0.880
CYCLE END #8	-0.080	-0.960
CYCLE END #7	-0.050	-0.930
TURN RECP AROUND	-0.070	-0.950
CYCLE END #8	-0.070	-0.950
CYCLE END #7	-0.070	-0.950

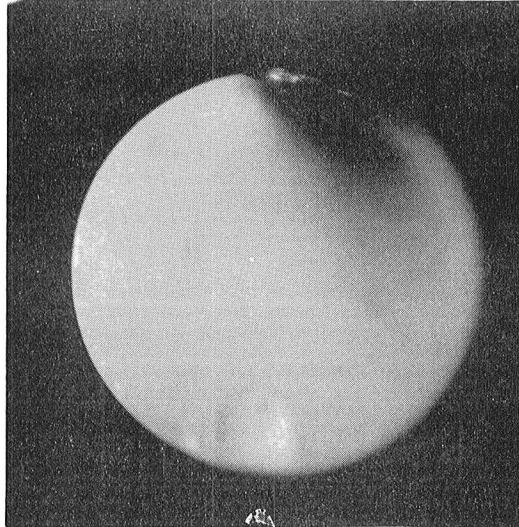
CONNECTOR PAIR #7

PLUG # 14
PLUG #10
RECP #5

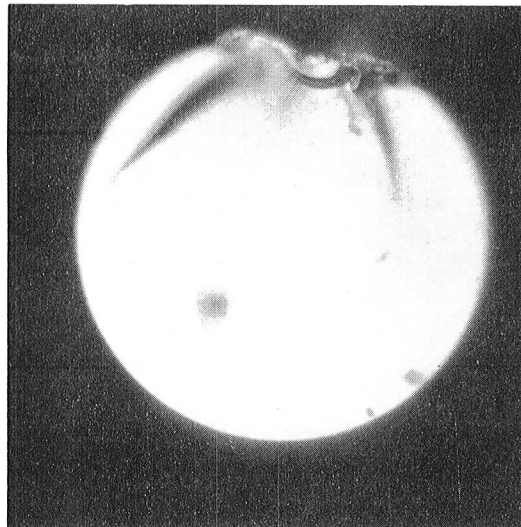
DATA COLLECTED ON 9-19-79



END PHOTOS



PLUG #14 END
FLATNESS= 12 μ m
ACCEPTED



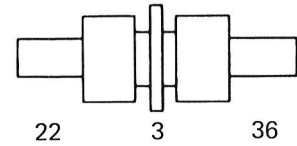
PLUG #10 END
FLATNESS= 8 μ m
ACCEPTED

LOSS MEASUREMENTS

	CHANGE	ABSOLUTE LOSS THIS MATING
INITIAL LOSS		-1.010
CYCLE END #14	-0.090	-1.100
CYCLE END #10	0.100	-0.910
TURN RECP AROUND	0.300	-0.710
CYCLE END #14	0.100	-0.910
CYCLE END #10	0.080	0.930

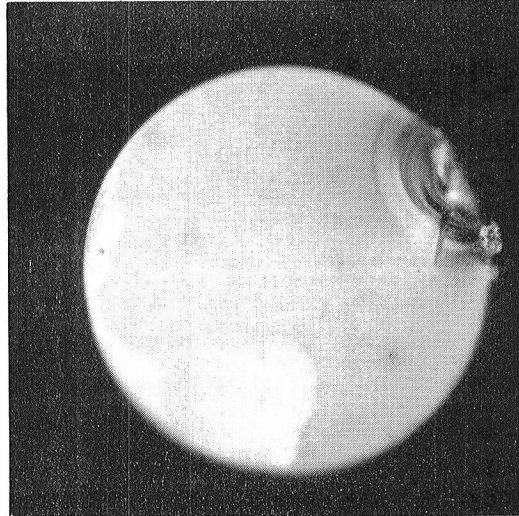
CONNECTOR PAIR #8

PLUG #22
PLUG #36
RECP #3

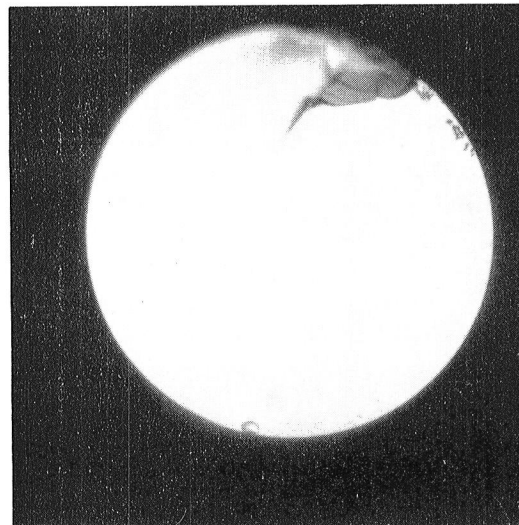


DATA COLLECTED ON 9-19-79

END PHOTOS



PLUG #22 END
FLATNESS= 9 μ m
ACCEPTED



PLUG #36 END
FLATNESS= 3 μ m
ACCEPTED

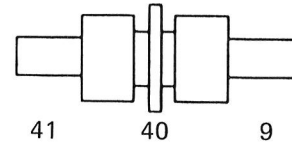
LOSS MEASUREMENTS

	CHANGE	ABSOLUTE LOSS THIS MATING
INITIAL LOSS		-0.580
CYCLE END #22	-0.030	-0.610
CYCLE END #36	-0.050	-0.630
TURN RECP AROUND	-0.160	-0.740
CYCLE END #22	-0.180	-0.760
CYCLE END #36	-0.160	-0.740

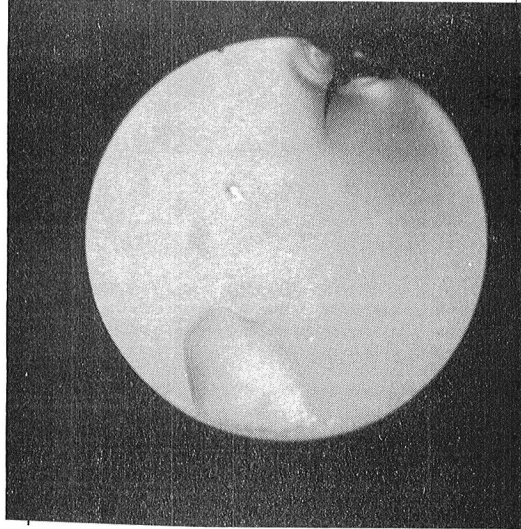
CONNECTOR PAIR #9

PLUG #41
PLUG #9
RECP #40

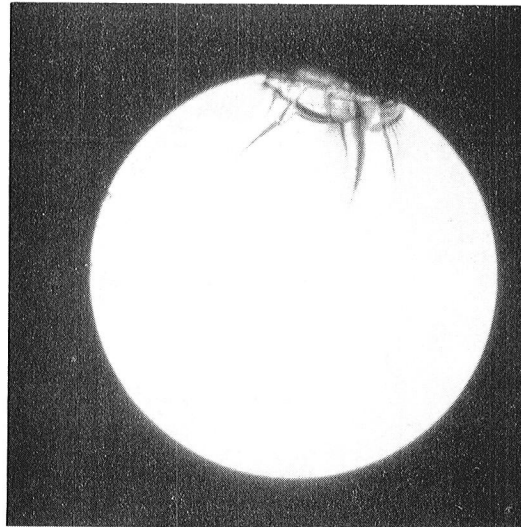
DATA COLLECTED ON 9-19-79



END PHOTOS



PLUG #41 END
FLATNESS= 6 μ m
ACCEPTED



PLUG #9 END
FLATNESS= 2 μ m
ACCEPTED

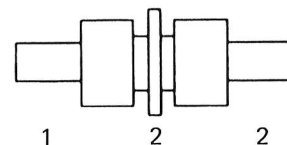
LOSS MEASUREMENTS

	CHANGE	ABSOLUTE LOSS THIS MATING
INITIAL LOSS		-0.860
CYCLE END #41	-0.040	-0.900
CYCLE END #9	-0.010	-0.870
TURN RECP AROUND	-0.400	-1.260
CYCLE END #41	-0.610	-1.470
CYCLE END #9	-0.590	-1.450

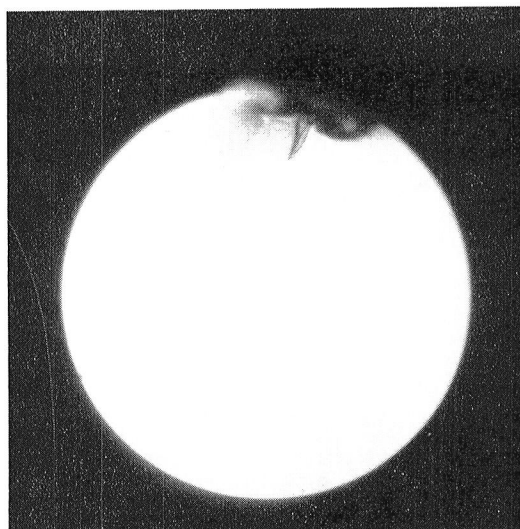
CONNECTOR PAIR #10

PLUG #1
PLUG #2
RECP #2

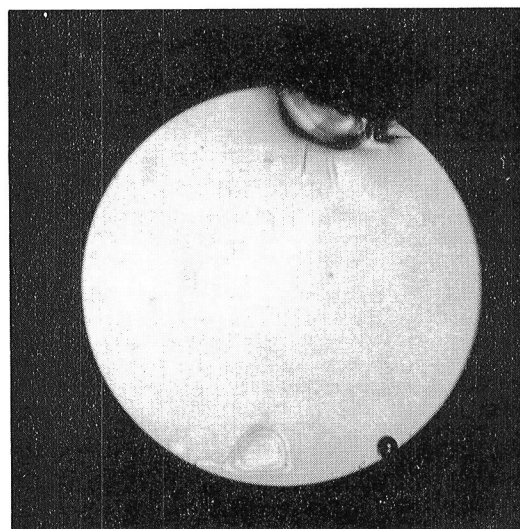
DATA COLLECTED ON 9-19-79



END PHOTOS



PLUG #1 END
FLATNESS= 1 um
ACCEPTED



PLUG #2 END
FLATNESS= 3 um
ACCEPTED

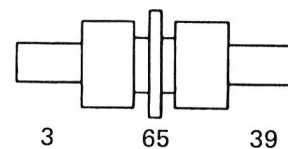
LOSS MEASUREMENTS

	CHANGE	ABSOLUTE LOSS THIS MATING
INITIAL LOSS		-0.940
CYCLE END #1	-0.140	-1.080
CYCLE END #2	-0.290	-1.230
TURN RECP AROUND	-0.010	-0.950
CYCLE END #1	0.020	-0.920
CYCLE END #2	0.015	-0.925

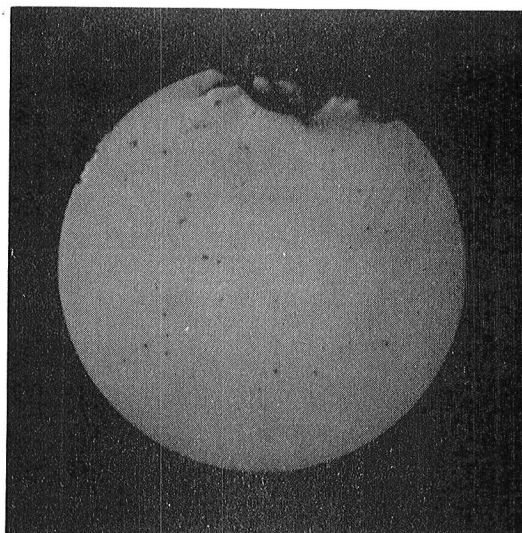
CONNECTOR PAIR #11

PLUG #3
PLUG #39
RECP #65

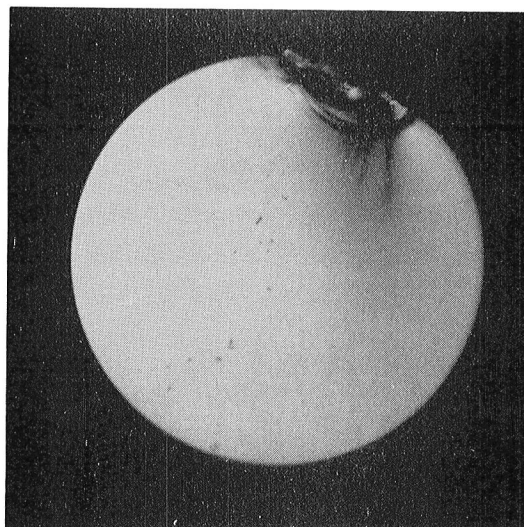
DATA COLLECTED ON 10-4-79



END PHOTOS



PLUG #3 END
FLATNESS= 1 um
ACCEPTED



PLUG #39 END
FLATNESS= 4 um
ACCEPTED

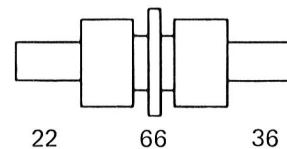
LOSS MEASUREMENTS

	CHANGE	ABSOLUTE LOSS THIS MATING
INITIAL LOSS		-0.899
CYCLE END #3	-0.060	-0.959
CYCLE END #39	-0.085	-0.984
TURN RECP AROUND	0.046	-0.853
CYCLE END #3	0.040	-0.859
CYCLE END #39	0.072	-0.827

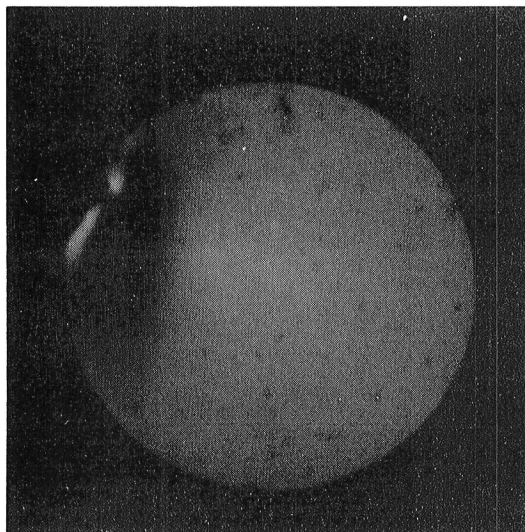
CONNECTOR PAIR #12

PLUG #22
PLUG #36
RECP #66

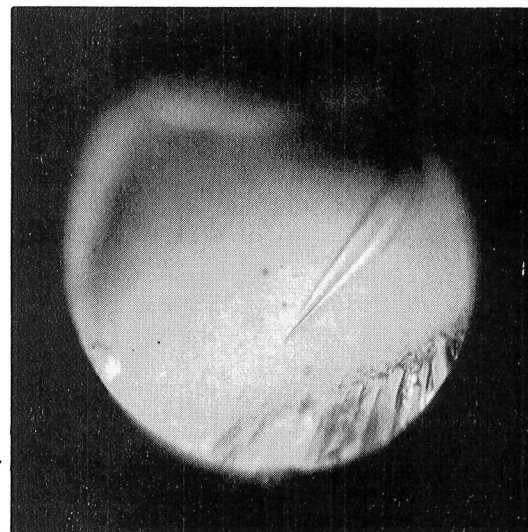
DATA COLLECTED ON 10-4-79



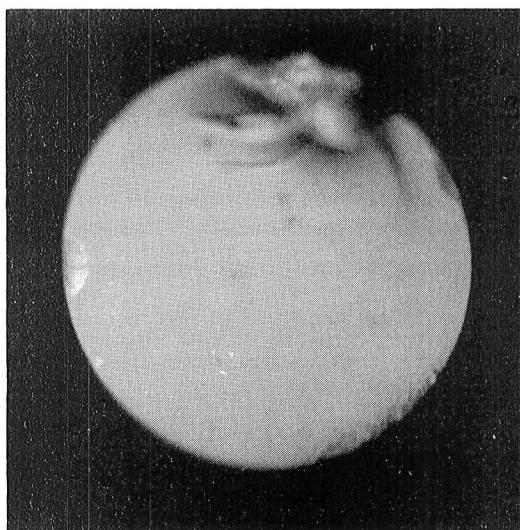
END PHOTOS



PLUG #22 END
FLATNESS= 4 μ m
ACCPETED



PLUG #36 END
FLATNESS= 4 μ m
REJECTED FOR
OVERALL QUALITY



PLUG #36 END
FLATNESS= 7 μ m
ACCPETED

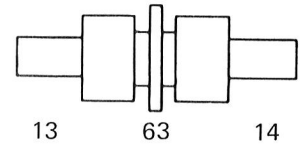
LOSS MEASUREMENTS

	CHANGE	ABSOLUTE LOSS THIS MATING
INITIAL LOSS		-1.220
CYCLE END #22	-0.020	-1.240
CYCLE END #36	-0.060	-1.280
TURN RECP AROUND	0.530	-0.690
CYCLE END #22	0.550	-0.670
CYCLE END #36	0.646	-0.574

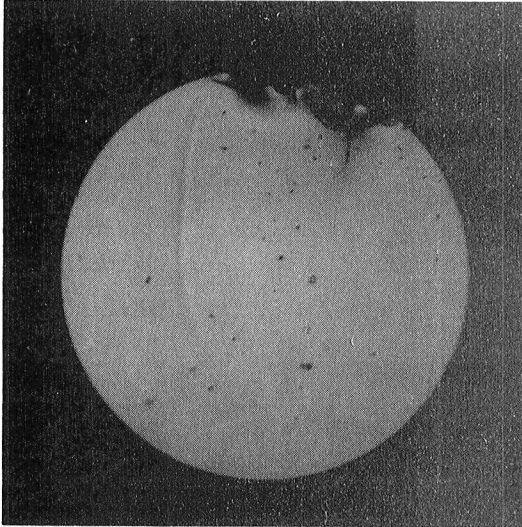
CONNECTOR PAIR #13

PLUG #13
PLUG #14
RECP #63

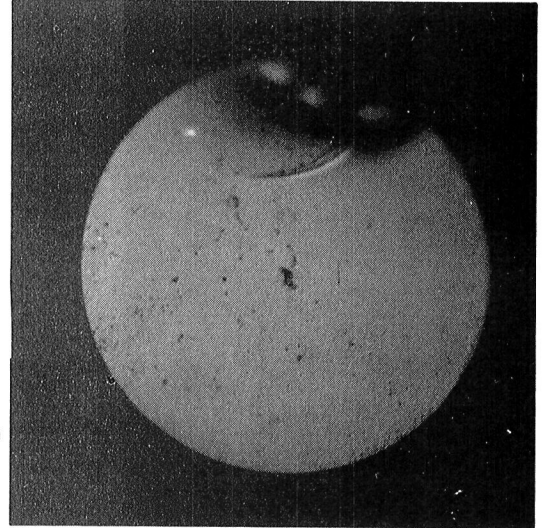
DATA COLLECTED ON 10-4-79



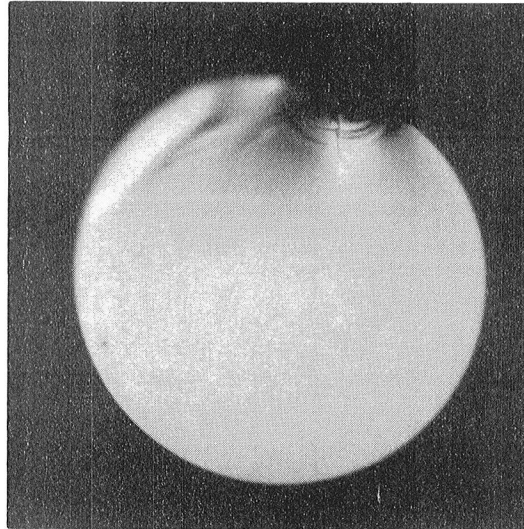
END PHOTOS



PLUG #13 END
FLATNESS= 2 μ m
REJECTED FOR
OVERALL QUALITY



PLUG #13 END
FLATNESS= 1 μ m
ACCEPTED



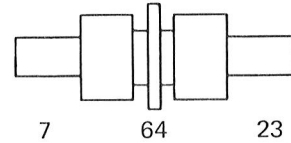
PLUG #14
FLATNESS= 6 μ m
ACCEPTED

LOSS MEASUREMENTS

	CHANGE	ABSOLUTE LOSS THIS MATING
INITIAL LOSS		-0.626
CYCLE END #13	-0.076	-0.702
CYCLE END #14	-0.100	-0.726
TURN RECP AROUND	0.053	-0.573
CYCLE END #13	0.051	-0.575
CYCLE END #14	0.038	-0.588

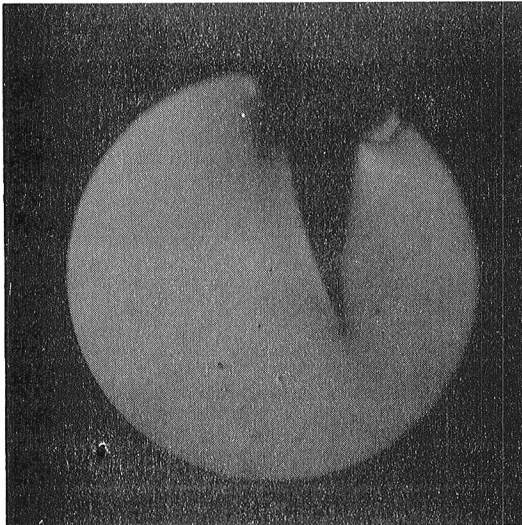
CONNECTOR PAIR #14

PLUG #7
PLUG #23
RECP #64

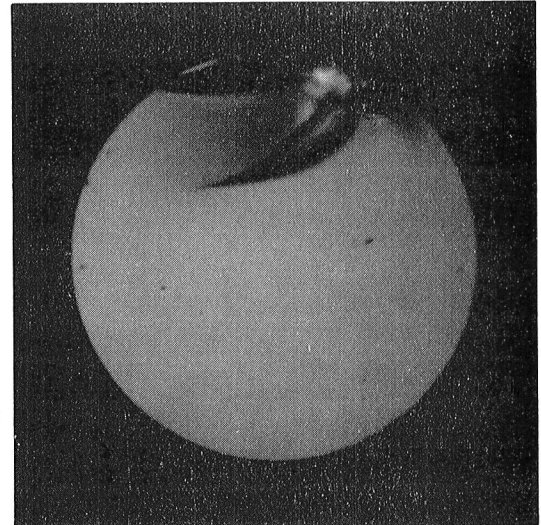


DATA COLLECTED ON 10-4-79

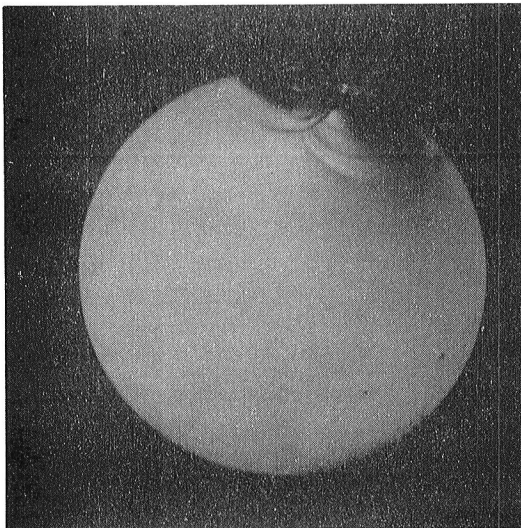
END PHOTOS



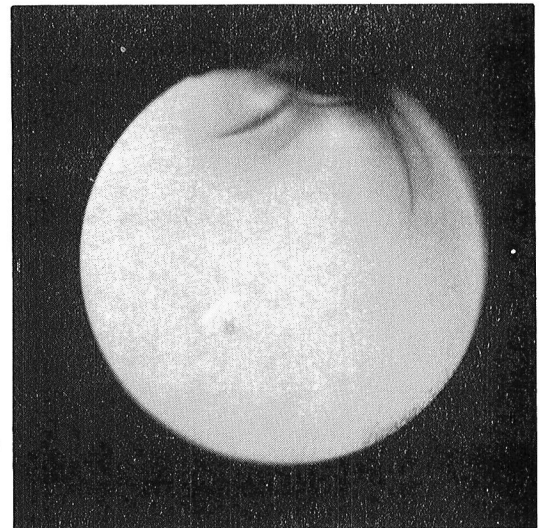
PLUG #7 END
FLATNESS=\$\$ μm
REJECTED FOR
SPUR



PLUG #7 END
FLATNESS= 5 μm
REJECTED FOR
SPUR



PLUG #7 END
FLATNESS= 1 μm
ACCEPTED



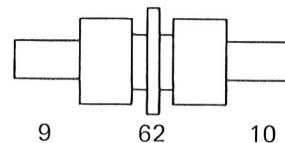
PLUG #23 END
FLATNESS= 4 μm
ACCEPTED

LOSS MEASUREMENTS

	CHANGE	ABSOLUTE LOSS THIS MATING
INITIAL LOSS		-0.462
CYCLE END #7	0.010	-0.452
CYCLE END #23	0.001	-0.461
TURN RECP AROUND	-0.166	-0.628
CYCLE END #7	-0.109	-0.571
CYCLE END #23	-0.145	-0.607

CONNECTOR PAIR #15

PLUG #9
PLUG #10
RECP #62

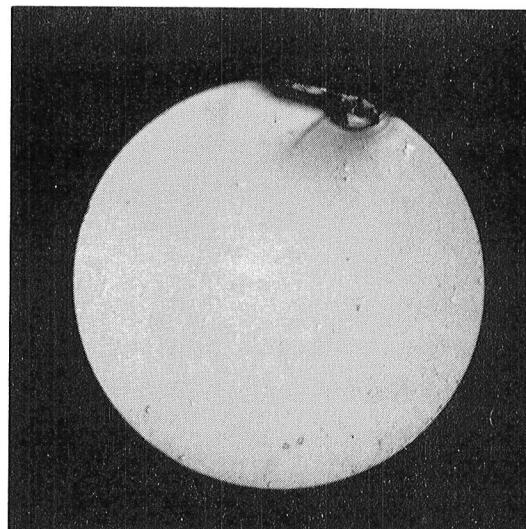


DATA COLLECTED ON 10-4-79

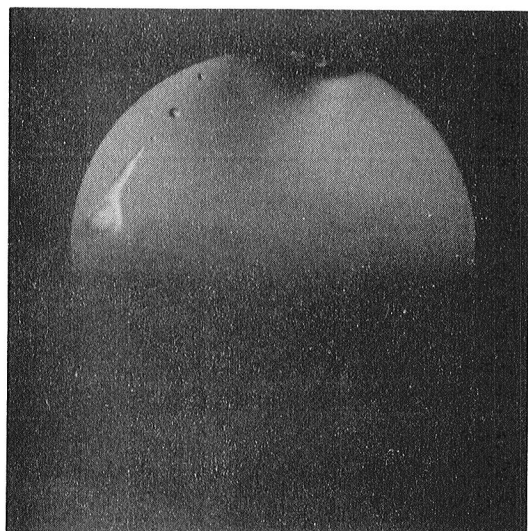
END PHOTOS



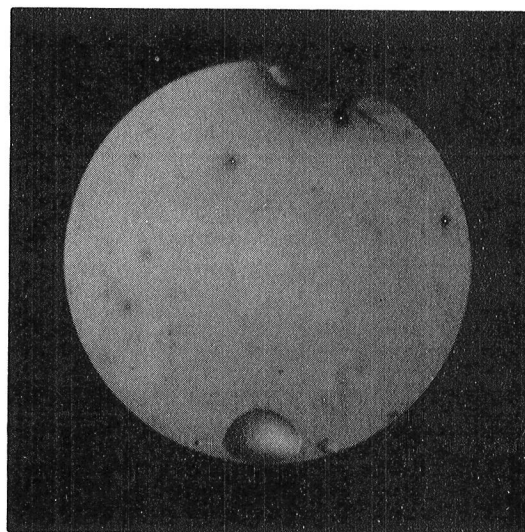
PLUG #9 END
FLATNESS=\$\$ um
REJECTED FOR
OVERALL QUALITY



PLUG #9 END
FLATNESS= 1 um
ACCEPTED



PLUG #10 END
FLATNESS=\$\$ um
REJECTED FOR
OVERALL QUALITY



PLUG #10 END
FLATNESS= 4 um
ACCEPTED

LOSS MEASUREMENTS

	CHANGE	ABSOLUTE LOSS THIS MATING
INITIAL LOSS		-0.840
CYCLE END #9	0.070	-0.770
CYCLE END #10	0.004	-0.836
TURN RECP AROUND	-0.086	-0.926
CYCLE END #9	-0.165	-1.005
CYCLE END #10	-0.095	-0.935

Appendix B

Program Listing

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0: "CONN.OR LOOP EVALUATION PROGRAM 6-21-79":
1: dim T$[16]
2: "DECISION":ent "WANT CONN EVALUATION ?NO=0,YES=1", P;if P=0;goto "LOOP"
3: goto "start"
4: "FACTOR":
5: ent "DID FACTOR CHANGE ? NO=0,YES=1",L
6: if L=0;ret
7: 0 F
8: ent "LOCK-IN""A""",J
9: ent "LOCK-IN""B""",K
10: ent "DET. CONV.""A""",M
11: ent "DET. CONV.""B""",N
12: KN/JM F
13: fxd 6
14: ret
15: "READ":
16: 0 V;0 R
17: for I=1 to 10
18: red 722,V;V+R R
19: next I;R/10 V;VF V
20: ret
21: "start":
22: ent "ENTER CONNECTOR TYPE",T$
23: spc ;prt "-----"
24: prt "CONNECTOR TYPE";spc 1;prt T$,"-----";spc
25: spc 1;prt "TYPE 1","MEASURE LOOP","CUT","INSTALL CONN."
26: prt "MEAS. CONNECTOR";spc 2
27: prt "TYPE 2","MEASURE LOOP","MEASURE BOTH","SIDES OF CONN."
28: prt "INSTALL","PRETERMINATED","CONNECTOR";spc 2
29: ent "ENTER MEASUREMENT TYPE",M;if M=2;goto "other"
30: "normal":
31: prt "ESTABLISH LOOP";spc ;dsp "ESTABLISH 800m LOOP";stp
32: dsp "Ready to meas. WITHOUT Conn.";stp
33: gsb "FACTOR"
34: 0 r1
35: for J=1 to 10
36: gsb "READ"
37: V+r1 r1
38: next J;r1/10 A
39: prt "Loop WITHOUT","CONNECTOR",A
40: "another":dsp "INSTALL CONNECTOR";stp
41: dsp "Ready to meas. WITH conn.";stp
42: gsb "FACTOR"
43: gsb "READ"
44: spc 1;prt "*****", "Loop WITH","Connector",V;spc
45: V B
46: 10log(B/A) C
47: prt "CONNECTOR LOSS","IN dB",C,"-----"
48: "reconnect1":
49: dsp "CYCLE CONNECTOR";stp
50: dsp "Ready to meas. RECONNECT";stp
51: gsb "FACTOR"
52: gsb "READ"
53: prt "Loop with',"RECONNECT",V;spc

```

```

54: V D
55: 10log(D/B) E
56: prt "RECONNECT DELTA","IN dB",E,"=====
57: ent "RECONNECT AGAIN?",S
58: ent "WANT TO REESTABLISH LOOP?",R;if R=1 and S=0;gto "start"
59: if R=0 and S=0;gto "another"
60: gto "reconnect1"
61: "other":
62: dsp "READY TO TAKE MEASUREMENT M1";stp
63: gsb "FACTOR"
64: gsb "READ"
65: prt "M1=",V;V A
66: spc 2
67: dsp "CUT LOOP & MEASURE M2";stp
68: gsb "FACTOR"
69: gsb "READ"
70: prt "M2=",V;V B
71: 10log(B/A) T;T*-1 T
72: prt "L2 IN dB=",T
73: spc 2
74: dsp "SPLICE & MEASURE M3";stp
75: gsb "FACTOR"
76: gsb "READ"
77: prt "M3=",V;V C
78: 10log(C/B) U
79: prt "S3 IN db=",U
80: spc 2
81: dsp "SPLICE & MEASURE M4";stp
82: gsb "FACTOR"
83: gsb "READ"
84: prt "M4=",V;V D
85: 10log(D/C) W
86: prt "CONNECTOR LOSS IN dB=",W
87: spc 2
88: dsp "SPLICE LOOP";stp
89: gsb "FACTOR"
90: gsb "READ"
91: prt "M5=",V;V E
92: 10log(E/D)-T X
93: prt "S4 IN dB=",X
94: spc 2
95: 10log(E/A)-(T+X+U) Y
96: prt "TOTAL CONNECTOR LOSS IN dB =",Y
97: spc 2
98: "reconnect2":dsp "REPEATABILITY TEST";stp
99: gsb "FACTOR"
100: gsb "READ"
101: prt "M6=",V;V G
102: 10log(G/E) Z
103: prt "RECONNECT DELTA IN dB=",Z
104: spc 2
105: ent "RECONNECT AGAIN ? NO=0,YES-1",S
106: if S=0;gto "start"

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107: gto "reconnect2"
108: "LOOP":
109: if r5=1;jmp 6
110: dsp "READY TO MEASURE LED";stp
111: gsb "FACTOR"
112: gsb "READ"
113: V Q
114: prt "LED TO REFERENCE RATIO=",Q
115: dsp "SPLICE LED TO LOOP ZERO LOCK-IN";1 r5;stp
116: gsb "FACTOR"
117: gsb "READ"
118: V r2
119: prt "LOOP=",r2
120: dsp "CUT & MEASURE LED";stp
121: gsb "FACTOR"
122: gsb "READ"
123: V r3
124: prt "LED=",r3
125: 10log(r2/r3) r4
126: prt "LOOP ATTENUATION=",r4;spc 2
127: gto "DECISION"
```

[illegible]

